



# Musculoskeletal Injuries in Climbers

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## Abstract

**Purpose of Review** This article aims to review the epidemiology of musculoskeletal injuries in climbers, risk factors leading to those injuries, and treatment and prevention strategies specific to climbers.

**Recent Findings** Most chronic climbing injuries occur in the upper extremities, especially the hands, and are due to overuse. Outdoor climbing is associated with a higher rate of injury than indoor climbing, and among indoor climbing sub-disciplines, bouldering has the highest injury rate. Further research is needed to identify specific techniques or training regimens that may lead to injury, and furthermore, if changing technique during training or competition could reduce these injuries.

**Summary** The types and incidences of most climbing injuries are fairly well documented. Evidence-based treatment and prevention strategies for chronic climbing injuries are limited, but many injuries can be managed conservatively with rest, activity modification, and rehabilitation. More work is needed to identify modifiable risk factors for climbing injuries.

**Keywords** Rock climbing · Climber · Upper extremity · Hand · Finger · Climbing medicine

## Introduction

Climbing is an immensely popular and rapidly growing sport. There are nine million active climbers in the USA and 25 million climbers worldwide according to the International Federation of Sport Climbing (IFSC) [1, 2]. According to insurance waivers, 1000 to 1500 people are climbing for the first time each day in the USA [3]. Its rapid growth is in part due to its popularity among young athletes; nearly 40% of active climbers are younger than 18 years old. The 2017 Outdoor Participation Report analyzed 24,134 surveys detailing American participation in outdoor activities [4]. 1.7% of all individuals older than 6 years old participated in bouldering, indoor climbing, or sport climbing in 2016. In individuals

aged 18–24 years, 3.5% participated in this type of climbing. For reference, 3.7% of individuals in this age group reported participating in downhill skiing.

Given its prevalence and growing popularity, providers specializing in sports and musculoskeletal medicine should expect to encounter climbers in their clinic. A basic knowledge of the sport and climbing-related injuries is critical in caring for these athletes. Therefore, the aim of this article is to provide a basic outline encompassing climbing sub-disciplines, common climbing-related injuries and risk factors for those injuries, treatment recommendations, and injury prevention strategies.

## Climbing Sub-disciplines

As a sport, climbing includes several sub-disciplines. The most notable breakdown is between outdoor and indoor climbing. Outdoor climbing occurs across a vast range of environments and can be further categorized based on the technique and equipment used to scale a route. Traditional, or “trad”, climbing involves ascending a route with a rope while placing removable anchors at various points deemed suitable by the lead climber. In ice climbing, ice axes and crampons are used to climb ice or mixed surfaces with a rope either affixed at the top of the route or secured along the way with

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removable anchors. “Mountaineering” is a term generally applied to situations involving climbing with ropes and sometimes crampons or ice axes with summiting a peak as the objective. In “free” or “solo” climbing, the climber does not utilize a rope while still scaling long routes. Falling during this type of climbing can result in serious injury or death.

Indoor climbing utilizes artificial surfaces that attempt to mimic an outdoor environment and offers a controlled setting for ample participation. National and international competitions primarily occur in this setting and include lead climbing, bouldering, and speed climbing.

Lead, or “sport”, climbing involves advancing a rope along a pre-set route of already fixed anchors. Bouldering implicates climbing without a rope over a short distance, usually not much higher than 20 ft, with large foam mattress pads placed at the base of the climb. Lastly, speed climbing involves scaling a preset route as fast as possible with safety provided by a rope secured at the top of the route.

For the first time in 2020, climbing will be an Olympic event, surely only enhancing the sport’s popularity. Lead climbing, bouldering, and speed climbing will all be featured, with the winner obtaining the best total score across the three events. Previously, climbers typically specialized in just one of these sub-disciplines. Now, professional climbers and training organizations are adjusting to athletes having to compete in all three sub-disciplines, and it is speculated that this change may lead to injury patterns not previously seen [5].

Importantly, climbing is also becoming a popular sport for those with physical disabilities. International paraclimbing competitions have been hosted by the IFSC since 2006 [6]. USA Climbing hosts an adaptive climbing national championship yearly with subcategories including neurological disability, visual impairment, upper extremity amputee, lower extremity amputee, seated, and youth [7].

## Climbing Injury Incidence

As the accessibility and popularity of climbing increases, so will the incidence of climbing-related injuries. From 2006 to 2015, there were an estimated 39,285 individuals who presented to Emergency Departments in the USA with climbing-related injuries [8•]. This represented a 36% increase in incidence from the previous time period. Most of those injured were male (70%), between the ages of 20 and 39 years old (57%), and suffered fractures or sprains (28% and 27%). About 12% required hospitalization. Many retrospective and prospective studies have reported the incidence of climbing injuries in relation to climbing hours. Incidence reports range from as low as 0.027 injuries per 1000 h to as high as 13 injuries per 1000 h [1•, 9•,10,11•,12•,13–15]. This range is likely due to variation among climbing settings, a lack of consistency in defining what constitutes an injury, and a lack

of consistency in what constitutes a climbing hour (for instance, does sitting at the base of a route in-between climbs count toward the climbing time?).

Injury rates and types vary among climbing sub-disciplines. Outdoor climbing has a higher injury incidence than indoor climbing and acute injuries tend to be more severe [13–15,16••]. Compared to lead climbing, mountaineering may have a lower incidence of injury. For example, a study of injuries on the Grand Tetons over a 5-year period noted an incidence of just 0.56 injuries per 1000 climbing hours [17]. Mountaineering typically involves climbing at a lower pitch for a longer duration than in lead-climbing, and this may result in the lower injury incidence. However, when they occur, injuries can be devastating. Campbell et al. found that injuries sustained in mountaineering often involved multiple body systems and included death [15]. The greater injury severity may be due to greater variability in climbing terrain involving crevasses, rock fall, extreme weather, and inaccessibility to emergency services, especially in climbers who have pre-morbid cardiopulmonary health conditions.

By comparison, at least in terms of acute injuries, indoor climbing is relatively safe. In 2012, the IFSC collected injury data for all athletes competing in the World Cup climbing series which includes lead climbing, bouldering, and speed climbing. Though the sample size was small, 6750 climbing hours with just five injuries total, the trend suggested bouldering to have the greatest injury rate at 1.47 injuries per 1000 h, lead climbing second at 0.74 injuries per 1000 h, and speed climbing third with zero injuries [13]. This is consistent with other studies ranking injuries in competitive climbing with the greatest injury rate seen in bouldering, followed by lead climbing, and lastly speed climbing with the lowest injury rate [12•, 14, 15]. These injury rates seem to parallel the inherent risk of large falls within each climbing sub-discipline. Bouldering is ropeless and large dynamic moves required for difficult problems make the competitor prone to falling. Lead climbing provides anchors at variable intervals, but large falls can occur if the climber has ascended past their last anchor point. With the use of a top-rope in speed climbing, large falls are essentially non-existent.

## Climbing Injuries

Acute climbing injuries most commonly involve the lower extremity and are very often the result of a fall, particularly in the outdoor setting [8•, 13, 18–20]. Chronic injuries most commonly involve the upper extremities including the fingers, elbows, hands, and shoulders. An overwhelming majority of those injuries involve the fingers [1•, 13, 16••, 21••]. This review will focus primarily on chronic injuries involving the upper extremity as these will be the most common injuries encountered by the musculoskeletal specialist.

## Finger and Hand

The flexor mechanism of the fingers is commonly described as a flexor pulley system. Annular ligaments hold the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) tendons closely to the metacarpals and phalanges, distributing flexor forces and allowing the tendons to slide freely during flexion and extension (Fig. 1). A good analogy to this system would be a fishing line passing through the eyelets on a fishing pole, where the pole segments are the metacarpals and phalanges, the line is the FDS and FDP tendons, and the eyelets are the annular ligaments. There are five annular ligaments on each digit, A1–A5, from proximal to distal. With a prevalence of 19–26% and comprising 33% of all climbing injuries as well as over half of all finger injuries, pulley rupture is one of the most critical climbing injuries to understand [1•, 22•].

A2 is the most commonly injured pulley, followed by A4 and A3, and lastly A1 and A5 [1•, 22•]. Of the fingers, the ring is the most injured followed by the middle, then the index finger. Understanding the mechanism behind pulley ruptures requires a basic understanding of various gripping techniques utilized in climbing.

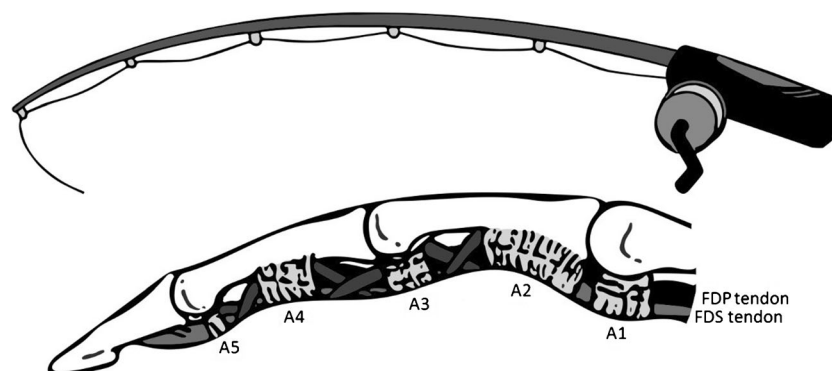
- The crimp grip (Fig. 2a) is used for narrow ledges or small holds with extreme flexion at the proximal interphalangeal (PIP) joint and hyperextension at the distal interphalangeal (DIP) joint. This puts tremendous force on the A2 pulley.
- The commonly utilized open hand grip (Fig. 2b) involves PIP joint flexion of about 60° and DIP joint flexion of about 30° thereby placing the greatest force on the A4 pulley.
- The pocket technique (Fig. 2c) involves jamming one or more fingers into a hole for grip, typically with minimal flexion at the PIP joint and near 90-degree flexion of the DIP joint thereby stressing the A4 pulley, FDP tendon, and the lumbricals.

A pulley rupture classically occurs during a dynamic move or a foot-slip during one of the above holds. Climbers often

report a loud popping sound at the time of injury followed by pain, swelling, and tenderness along the volar finger. Plain films may show an avulsion fracture and can screen for other pathology, but diagnosis of a pulley injury often requires either MRI or ultrasound. Pulley ruptures will appear as volar displacement of the tendon at rest that is enhanced with flexion resistance. Ultrasound may have better resolution than MRI and may be more sensitive for partial tears but relies heavily on user experience [22•, 23]. The mean tendon phalanx distance on either MRI or ultrasound helps define the presence of a rupture with 2.0 mm being the cutoff for rupture. Treatment for single-pulley rupture is conservative and surgery is usually only required if multiple pulleys are ruptured [24]. In general, conservative treatment involves up to 2 weeks immobilization with tape or thermoplastic ring, easy climbing at 4 to 12 weeks, and return to full climbing at 3 to 6 months depending on grade of injury. Prevention strategies attempt to mitigate risk factors for pulley injury, and general recommendations include avoiding dynamic moves from crimp grips, using an open hand technique where possible, and ensuring proper warm up.

Flexor tenosynovitis, or a thickened flexor pulley, is a common overuse climbing injury. Climbers often present with insidious onset pain on the volar finger surface along the proximal phalanx especially after extended climbing. Finger locking can also sometimes occur. Flexor tenosynovitis or “trigger finger” in the general population occurs at the A1 pulley, while in climbers the A2 pulley is most often involved. On either MRI or US imaging, the normal thickness of the A2 pulley should be between 0.04 and 0.06 cm. A symptomatic flexor tenosynovitis will usually measure between 0.11 and 0.29 [25, 26]. Treatment is generally conservative with rest and activity modification. Steroid or hyaluronic acid injections can be considered for pain relief if needed. Refractory cases might require surgical release, but this is rare. Ultrasound-guided release may be attempted by an experienced provider [25, 26].

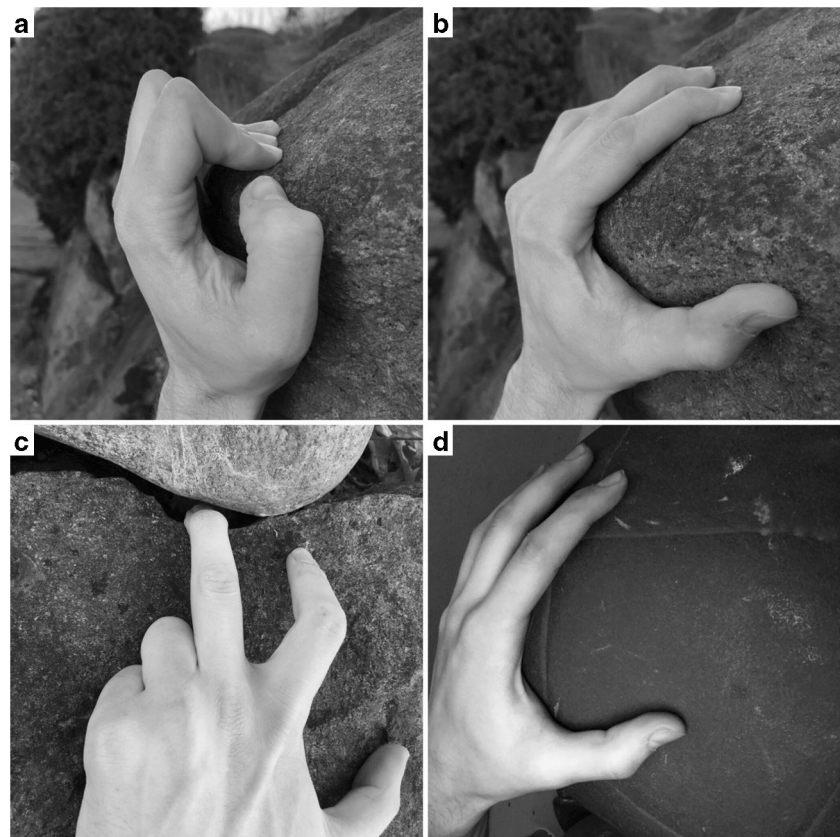
The lumbricals originate from the FDP tendon, attach on the extensor expansion near the MCP joint, and are responsible for flexing the MCP joint and extending both the PIP and



**Fig. 1** Flexor pulley system. The flexor pulley system acts similarly to a fishing line passing through the eyelets on a fishing pole. In this analogy, the pole segments are the metacarpals and phalanges, the line is the flexor

digitorum profundus (FDP) and flexor digitorum superficialis (FDS) tendons, and the eyelets are the annular ligaments (pulleys). There are five annular ligaments on each digit, A1–A5, from proximal to distal

**Fig. 2** Climbing grips and holds. **a** Crimp grip. **b** Open-hand grip. **c** Pocket technique. **d** Sloper hold



DIP joints for each finger. In climbing, lumbrical injuries occur when one finger is flexed and the adjacent finger is extended while force is placed on the extended finger. The extreme difference in length between one FDP tendon and the adjacent tendon in this position can stretch and tear adjacent lumbricals (lumbrical shift syndrome). The pocket technique is the main risk factor for this injury. Treatment is rest and early gentle range of motion exercises to prevent contracture formation [27]. Prevention strategies revolve around avoiding extreme flexion of one finger with extension of an adjacent finger. If the pocket technique is used with one or more fingers, flexing adjacent fingers at the PIP rather than the MCP may reduce lumbrical stress by decreasing the length discrepancy between adjacent FDP tendons and lumbricals.

Swelling of the finger joints, or capsulitis, is common in climbers [28••]. Continuous holds, particularly with a crimping grip, can put excessive stress on the cartilaginous surfaces of the PIP joints. This can lead to chronic synovial irritation, synovial hypertrophy, and inflammation. This may present as chronic swelling and aching of the PIP joints and associated morning stiffness. This constellation of symptoms should be distinguished from autoimmune conditions such as rheumatoid arthritis which might present similarly. Treatment involves activity reduction, NSAIDs, stretching, and modalities. Corticosteroid injections can be considered for refractory cases.

Osteoarthritis of the finger joints can be seen in climbers as well. Whether or not climbing leads to finger osteoarthritis, and to what degree, is not fully known. Osteoarthritis prevalence was originally thought to be very low in the climbing population. Studies by Bollen, Rohrbough, and Sylvester in the 1990s and 2000s determined that climbers do not have a higher incidence of osteoarthritis compared to age-matched controls [29–31]. More recent critiques of these studies argue that the x-rays utilized were mostly in the AP view and may not show expected osteoarthritis patterns on the flexor or extensor surface that would be more likely in climbers. In 2011, Allenspach examined the hands of 31 climbers with a mean 20 years of climbing experience utilizing AP and lateral x-rays [32]. They found osteophytes in 84% of PIP joints and 68% of DIP joints. However, they did not find subchondral cyst formation or joint space narrowing that one might typically see with osteoarthritis. Though these findings help us better understand osteoarthritis in climbers, it is debatable whether these osteophytes are clinically relevant.

The unique stresses of rock climbing can sometimes produce unexpected injuries; a stress fracture to the hook of the hamate being one example. This can occur with repetitive use of an undercling grip (reaching under a hold with the palm up, as if opening the trunk of a car) in which ulnar deviation and flexion result in the flexor tendons forcibly pressing against the hook of the hamate ultimately resulting in fracture [33].

Climbers often present with pain at the ulnar side of the palm and are tender to palpation over the hook of the hamate. The hamate pull test can help confirm a hamate stress fracture. To perform this test, one hand is placed with fingers pressed on the hook of the hamate and the other hand holds the ring and pinky finger and the wrist is placed under ulnar deviation. This will reproduce the pain. When the wrist is taken out of ulnar deviation, the pain resolves [33]. Plain films may be ordered first, but if they are negative this should be followed up by either CT or MRI. Lutter et al. followed 12 climbers in Germany and Switzerland with atraumatic ulnar palm pain [33]. Ten had a hook of the hamate fracture, two had no clear fracture, nine were successfully treated with 6–8 weeks of casting, and three required surgical treatment: one immediately and the other two from nonunion after casting. Fortunately, most returned to pre-injury activity by 6 months.

As in other youth sports, epiphyseal injuries can occur; however, in climbing, these injuries occur in the fingers. It is critically important to be able to recognize these growth plates, or Salter-Harris, fractures, as failure to do so can result in permanent finger deformity. Schoffl reports an alarming incidence in young climbers; of 16 climbers less than 14 years of age presenting with finger pain, 14 (87.5%) had epiphyseal fractures [21••]. Climbers with this injury typically present with joint swelling and finger pain during and after climbing. Definitive diagnosis is made with MRI. Training via use of a campus board (a series of thin horizontal slats against a wall from which the climber hangs, ascends, and descends) is thought to be a risk factor for this injury, particularly as such training relies on a crimp grip, but definitive evidence is lacking. Because of this, many advise against campus board training for all climbers less than 18 years old altogether while others suggest limited use in a controlled setting may be reasonable.

Lastly, a variety of hand masses can bring a climber into clinic. Flexor tendon sheath ganglion cysts are the most commonly encountered. They are more common in females in a 3:1 ratio, are generally found in ages 20 to 40, are near the A1 and A2 pulleys, and more commonly appear in the middle, followed by the ring finger [34]. They should be confirmed with ultrasound as being non-compressible and nonvascular before any intervention is performed. They will often respond to aspiration, fenestration, or corticosteroid injection, though occasionally require surgical removal for refractory cases [34]. The second most encountered hand mass is a giant cell tumor of the flexor tendon sheath. On ultrasound, they will appear as a hypoechoic, well-circumscribed mass, vascular, with adjacent cortical irregularity [35]. Other common masses encountered are glomus tumors, which are hypervascular arteriovenous malformations usually found under the volar surface of the finger nailbed and are painful, and lipomas, which are nonvascular fat-filled masses that are generally non-painful and commonly found in the thenar region.

## Wrist and Elbow

Injury to the triangular fibrocartilage complex (TFCC) is commonly seen in climbers presenting to our clinic despite a lack of literature on the subject. This typically presents as ulnar-sided wrist pain, classically aggravated when gripping large “sloper” holds (Fig. 2d) or when topping out at the end of a route. Physical exam reveals tenderness between the pisiform and the volar surface of the ulnar head at the area of the ulnar styloid process and flexor carpi radialis tendon (positive fovea sign). Treatment involves resting from climbing and wrist immobilization for several weeks before a slow return to activity. Pharmacologic treatment includes NSAIDs and possible corticosteroid injection. If initial treatment fails, an MR arthrogram of the wrist can offer a more definitive diagnosis and further characterize the injury. Surgical intervention is typically reserved for injuries that coincide with distal radial-ulnar instability.

Just as runners can develop stress reactions from excessive repetitive tibial loading, climbers can develop stress reactions involving the wrist [28••]. Insidious onset of distal radial or mid-carpal wrist pain with focal tenderness should raise concern for an overuse stress reaction. MRI is necessary for a definitive diagnosis and will reveal bone marrow edema within the distal radius, lunate, or scaphoid. The presentation can be similar to Kienbock’s disease or avascular necrosis of the lunate, which involves a loss of the blood supply to this bone [28••]. While Kienbock’s disease often requires surgical intervention, a stress reaction from overclimbing simply requires rest. Typically, a 12–16-week break from climbing is required for full recovery. If symptoms persist despite prolonged rest, a repeat MRI may be warranted to ensure bony healing.

Both brachialis tendonitis and common flexor tendinopathy (golfer’s elbow) can be referred to as “climber’s elbow.” Brachialis tendonitis is more common in climbing than with other sports because many upper extremity movements while climbing are performed in complete pronation. While the biceps brachii inserts onto the radius and flexes the elbow and supinates the forearm, the brachialis attaches to the ulna and does not pronate or supinate. During complete pronation, the brachialis provides the bulk of the force required to generate elbow flexion with the biceps contributing very little in this position. Common flexor tendinopathy is also frequently seen among climbers since wrist and finger flexion is used with most climbing holds. Acutely, climbers will tell you their forearms feel “pumped.” Over time, repeated flexion can lead to common flexor tendinopathy and pain at the medial elbow. Management of both injuries is conservative and typically involves rest from climbing followed by rehabilitation with use of ice and NSAIDs for symptomatic relief.

## Shoulder

The shoulder is the second most commonly injured anatomic site in climbers representing 40% of upper extremity injuries

and 17% of all climbing injuries [21••]. SLAP (superior labrum from anterior to posterior) tears are the most common injury, comprising about a third of all shoulder injuries. Shoulder impingement, anterior dislocations, shoulder sprains, and supraspinatus tendinosis are all also relatively common. These injuries are common in the general athletic population, and treatment does not differ substantially in climbers.

## Risk Factors and Prevention Strategies

Only recently have studies begun to investigate risk factors for injury in climbers, and prevention strategies are still being developed. Male climbers suffer more injuries in total and more chronic injuries than female climbers [8•, 16••]; however, female climbers suffer more injuries to the wrist, foot, and ankle [16••]. Elite climbers seem to suffer a greater number of chronic climbing injuries than inexperienced and recreational climbers, likely related to the amount of time dedicated to the sport and possibly due to specialization [1•, 12•, 16••, 36]. Youth climbers are clearly at risk of suffering epiphyseal fractures [21••], but other injury risk factors in this cohort are lacking.

In a systematic review of the literature, Woollings et al. found no benefit to warm up and stretching, with one study showing a possible increased risk of injury with stretching [12•]. Yoga, increasing the number of spotters, instructors present, and safety mats for bouldering showed no difference in injury rates. Taping wrists and strength training were shown to decrease injury rates, but time off from sport, heating hands before climbing, glucosamine and other supplements, and corticosteroid injections showed no significant difference in injury rates. Several authors have proposed that changing footwear could help prevent chronic foot injuries [16••, 18]. Footwear inadequately designed for women may be one reason women seem to suffer a greater proportion of injuries to the foot and ankle [16••]. Additionally, many climbers may be wearing shoes too small for their feet thereby leading to increased foot stress and chronic injury [18].

Lastly, climbing form may be key to injury prevention, but formal evidence is lacking. Experienced coaches preach the importance of engaging the core, back muscles, and periscapular muscles while climbing as those climbers relying on grip strength alone will fatigue quickly. Climbers should be encouraged to practice optimal hanging technique, and it can be helpful to have a trainer or coach observe the climber's static hang. Ideally, the climber should hang with an open-hand grip, the elbows bent around 150 degrees, the scapula retracted and depressed, and the cervical spine neutral.

## Conclusion

Climbing is vastly popular and participation continues to increase. Injuries in this group of athletes are unique to the sport,

and a basic ability to recognize and treat these injuries is critical. The types and incidences of most climbing injuries are well documented. Most chronic climbing injuries occur in the upper extremities, particularly in the fingers and hands, and are due to overuse. Evidence-based treatment and prevention strategies for chronic climbing injuries are limited, but many injuries can be managed conservatively. While there has been some research to identify risk factors associated with injuries in climbers, there is a paucity of research surrounding how climbing techniques and training practices may lead to injury. This is particularly notable in youth climbers, where essentially no data exists to guide training practices. Further research should examine the training habits of climbers and whether modifying these practices could lead to preventing injury.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflicts of interest.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

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